Shipboard Applications of Non-Intrusive Load Monitoring

MIT
Department of Electrical Engineering and Computer Science

DIAS Program Review
August 2004

Funding:
Office of Naval Research
“Control Challenge” Project

Monitoring Electrical Loads on Ships

- Performance-based monitoring is essential for operational readiness.
- Automated control enabled by monitoring can reduce manning levels.
- Automated monitoring and control may react faster than a human in an emergency.
- Integrated Condition Assessment System (ICAS) and MFM illustrate beginning efforts on the road to this vision.

Philosophy of Dual Use:

Why not pull information out of existing power cabling instead of using dedicated sensors?

Promising Capabilities of NILM (Ultimate Goal)

- Backup indicator of system performance.
- Automatic fault detection and system reconfiguration.
- Assistance with fault correction.
- System control.
- Component trending for condition-based maintenance.

Scope of the ONR "Control Challenge" at MIT

13 Field installations, 60 Gbytes field data, new non-intrusive diagnostic system under active development, leading to "deliverable" monitoring hardware, software, and field installations/tests.

- **Field work on ONR YP**
- **Collaborative diagnostics at Purdue.**
- **Development of shipboard. monitoring system as a platform for diagnostics and controls.**
- **Additional data from the WHOI research vessel "Oceanus".**

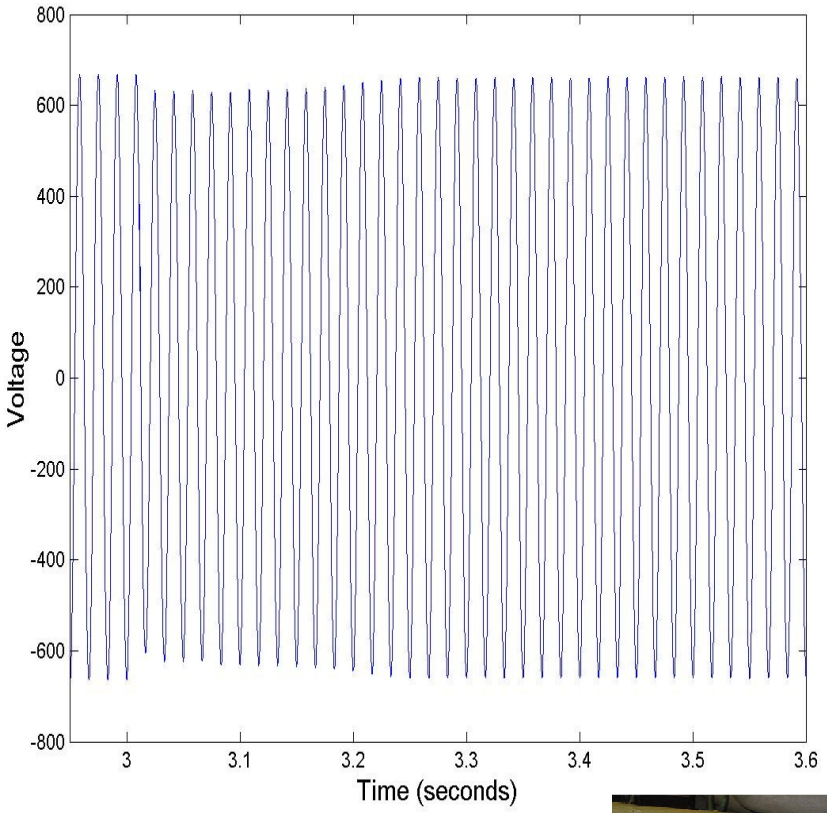
Collaborative with field tests conducted on the USCGC Seneca as part of ESRDC.

Interest (Problems for the Crews)

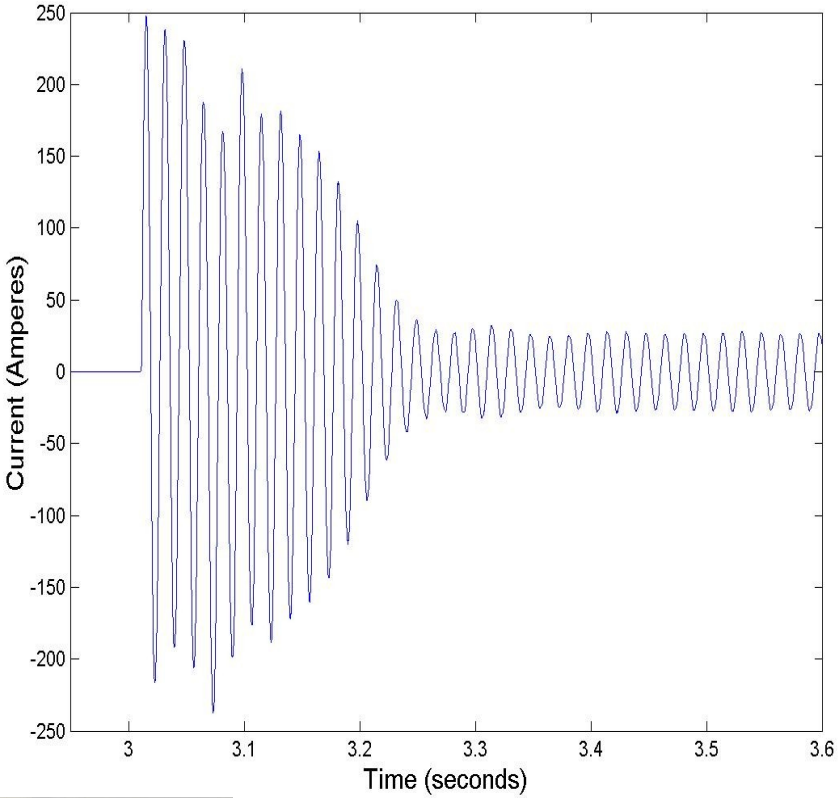
- **Auxiliary Sea Water (ASW)**
- **Cycling Systems, e.g., sewage dispos**
- **Steering Gear**
- **HVAC**
- **Roll-Fin Control**
- **Propellor Pitch Control**
- **Electrical Distribution (Transformers**
- **Anchor Windlass**
- **Winch**
- **Bow Thruster**

Non-Intrusive Load Monitoring

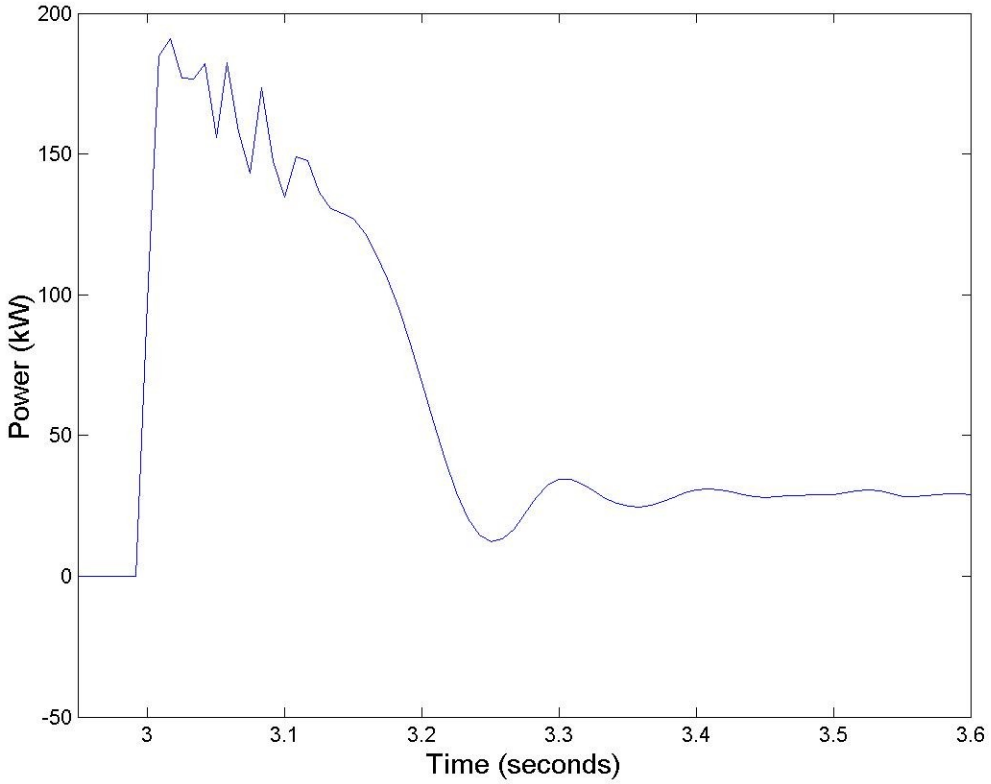
Voltage



Current

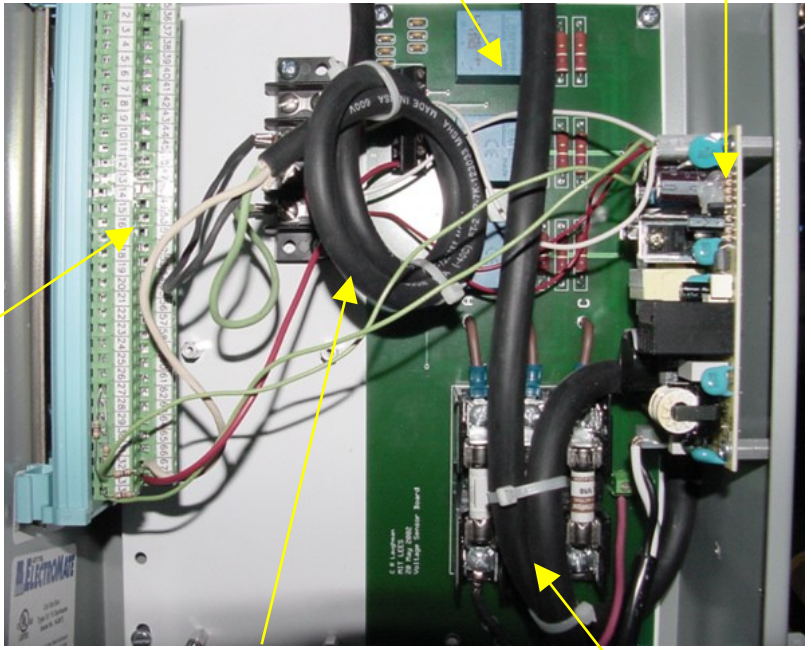


Non-Intrusive Load Monitoring Fundamentals

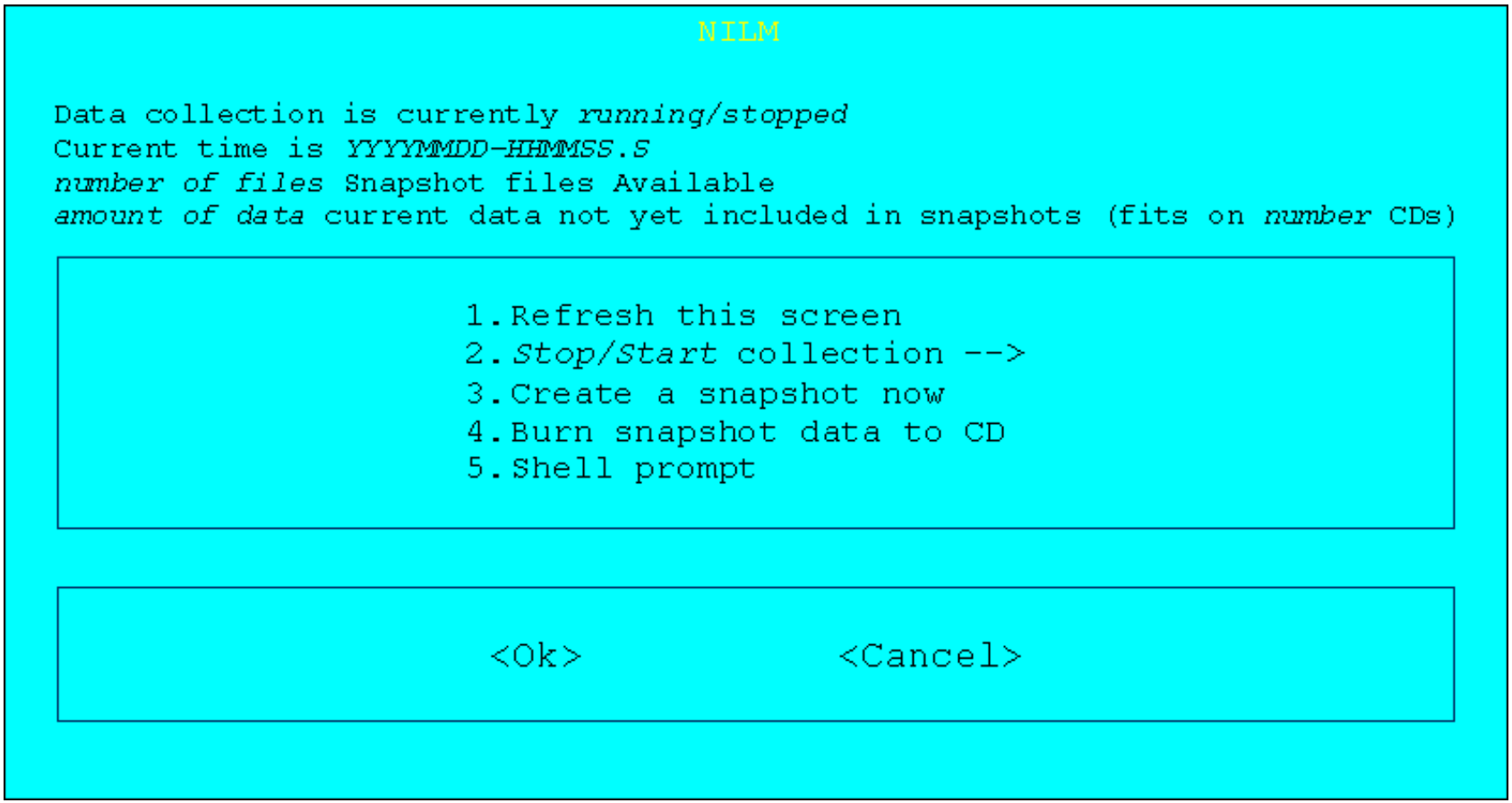


- Voltage/Current combine to produce power envelope.
- P and Q produced from phase. relationships
- Harmonics also produced.

Typical Shipboard NILM Installation



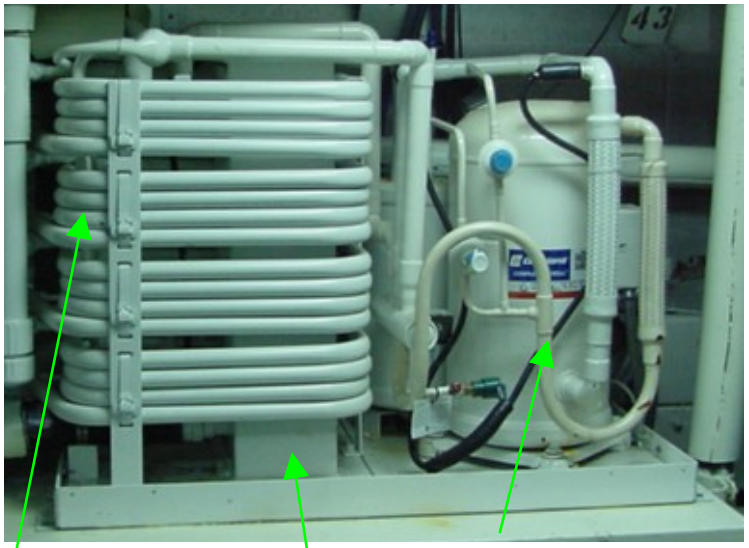
Automated Data Collection


NILM
Data collection is currently running/stopped
Current time is YYYYMMDD-HHMMSS.S
number of files Snapshot files Available
amount of data current data not yet included in snapshots (fits on number CDs)
1. Refresh this screen
2. Stop/Start collection -->
3. Create a snapshot now
4. Burn snapshot data to CD
5. Shell prompt
<Ok>
<Cancel>

ONR HVAC System

- Two Chillers, two heater banks, one CW pump, and one SW pump.

One working CW pump



SW cooling coils

CW/Refrigerant HX

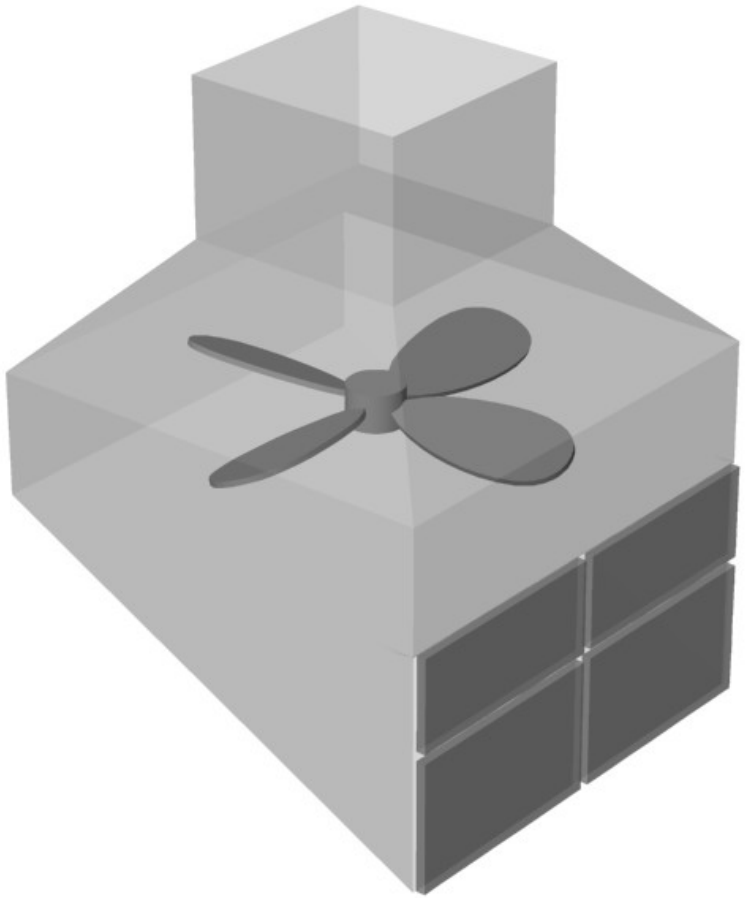
Compressor

HVAC Fan

Ducted HVAC Fan with filter array.

Found (in one form or another) on board all test ships.

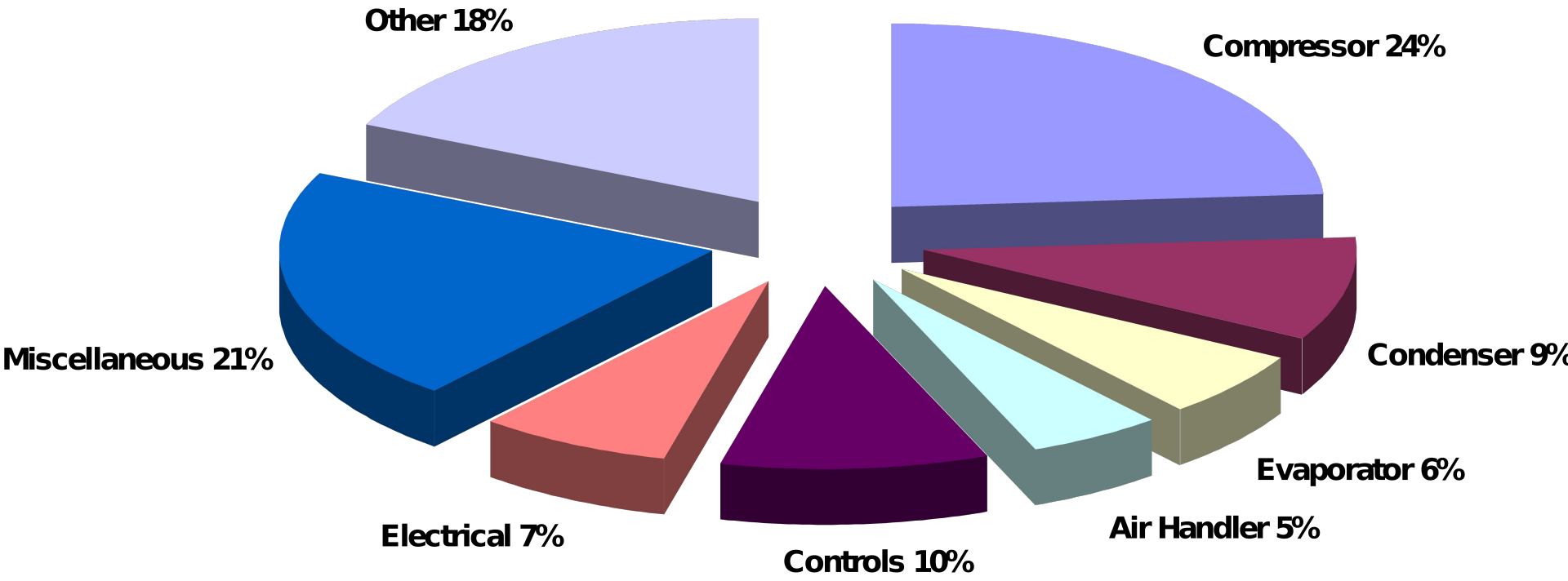
Experiments conducted on-board, underway, and at land-based test site.



HVAC Test Site

Repair Cost by Fault Category

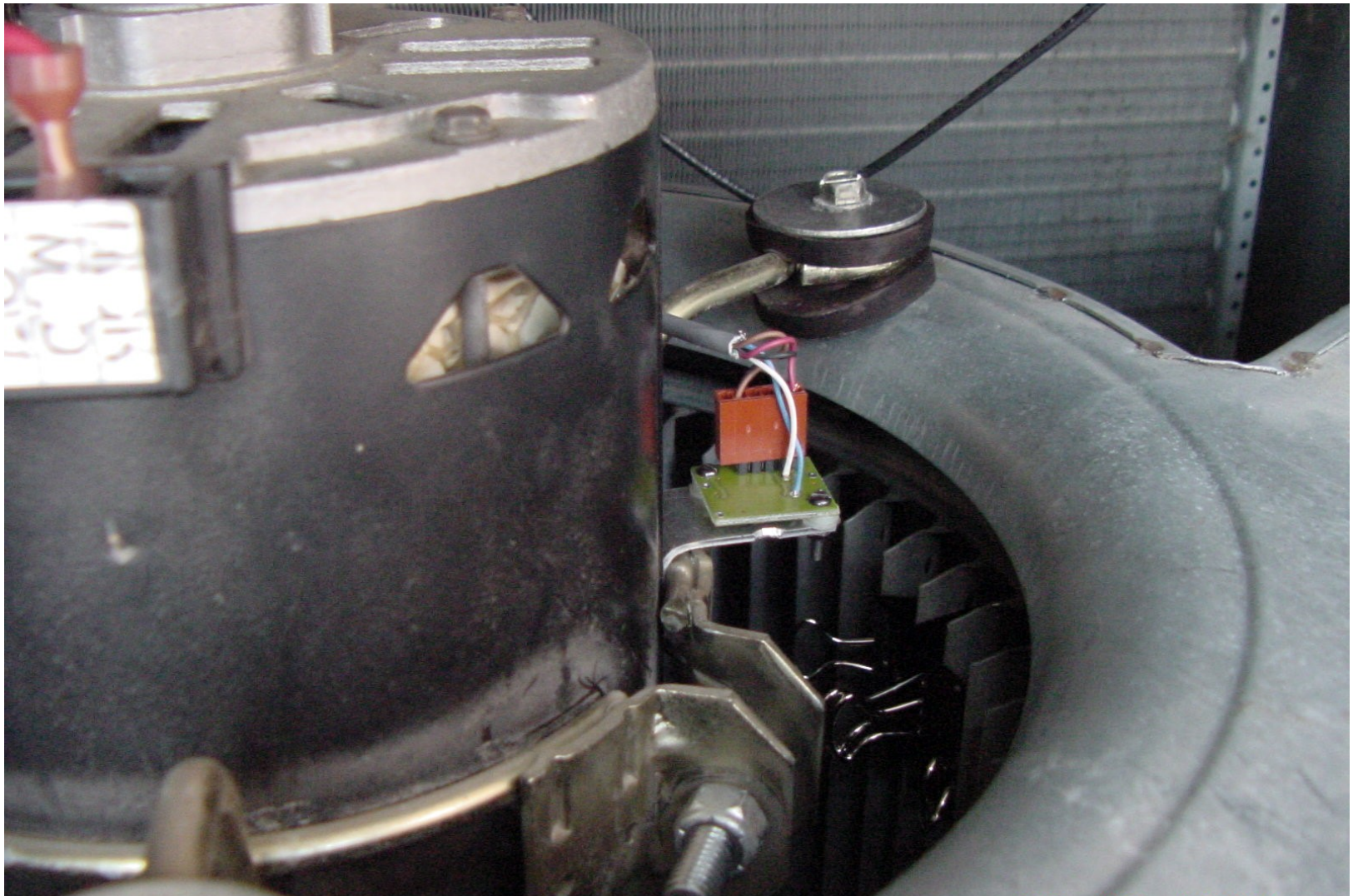
ueker and Braun 1998, with similar results from YP survey)



Tested Faults

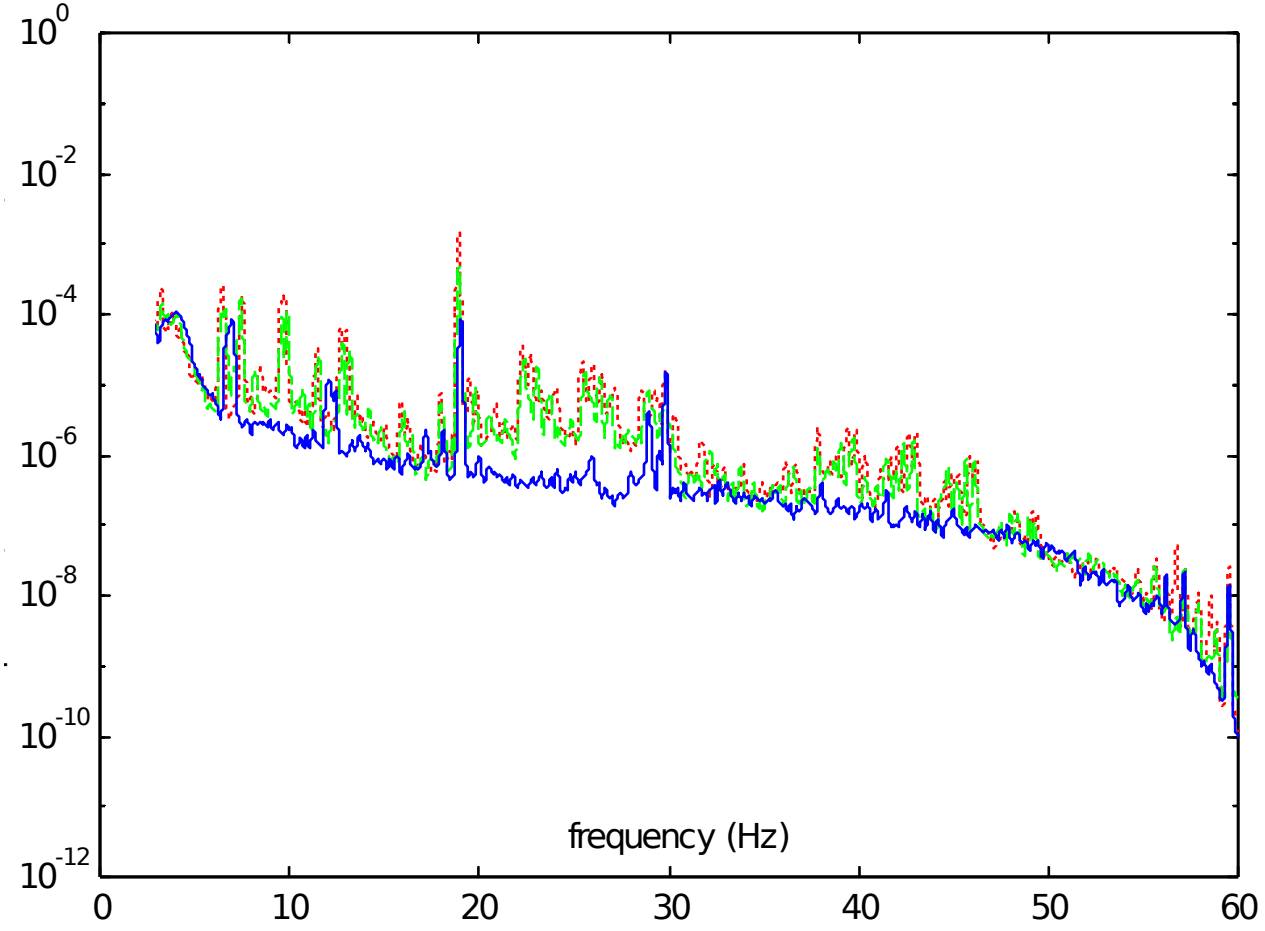
- Short Cycling
- Refrigerant Overcharge
- Refrigerant Undercharge (or loss)
- Volumetric efficiency loss (vapor bypass)
- Fan blockage (evaporator or condenser)
- Fan Imbalance (evaporator or condenser)

Fan Imbalance

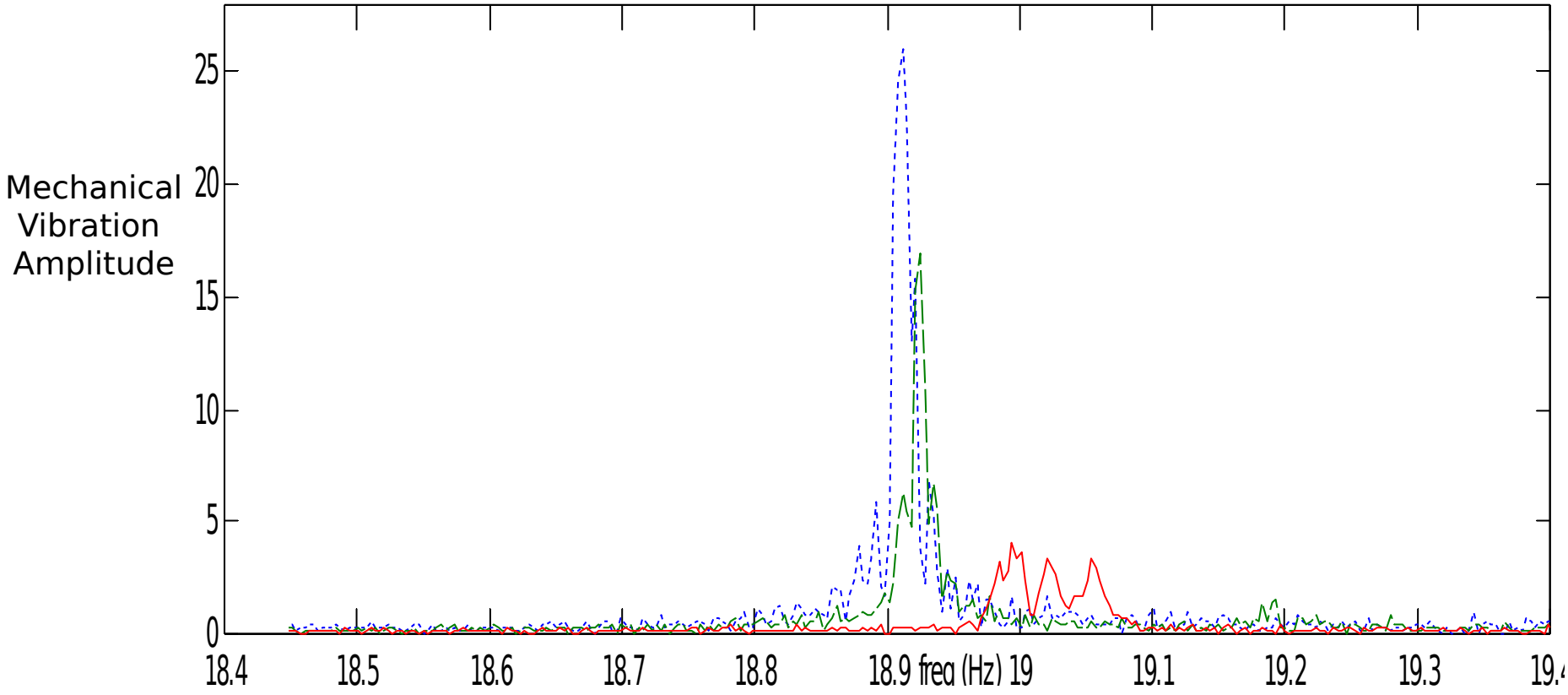


Supply Fan Spectrum with 0, 8, 16g

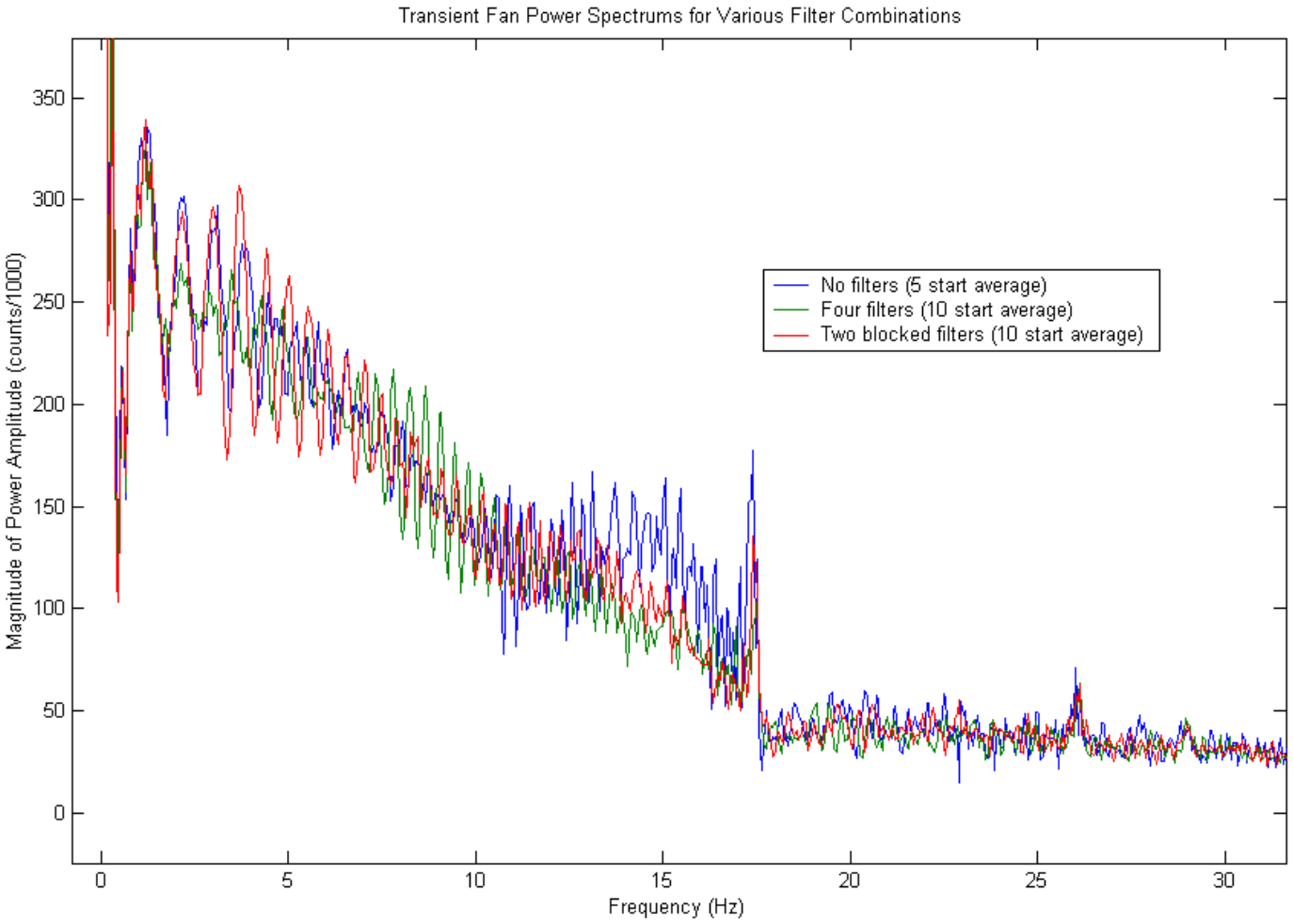
Mechanical Vibration Amplitude



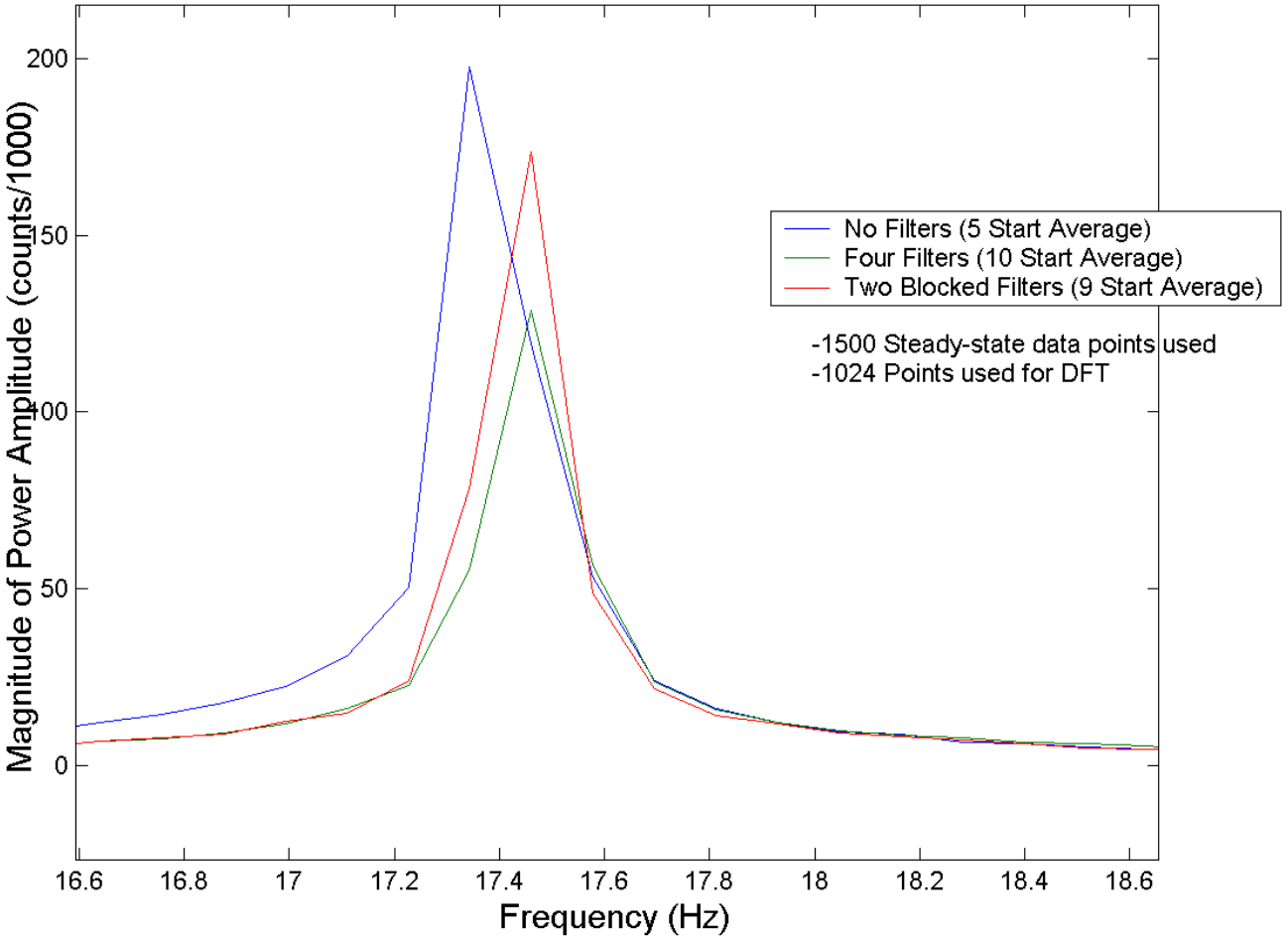
Supply Fan Spectrum with 0, 8, 16g



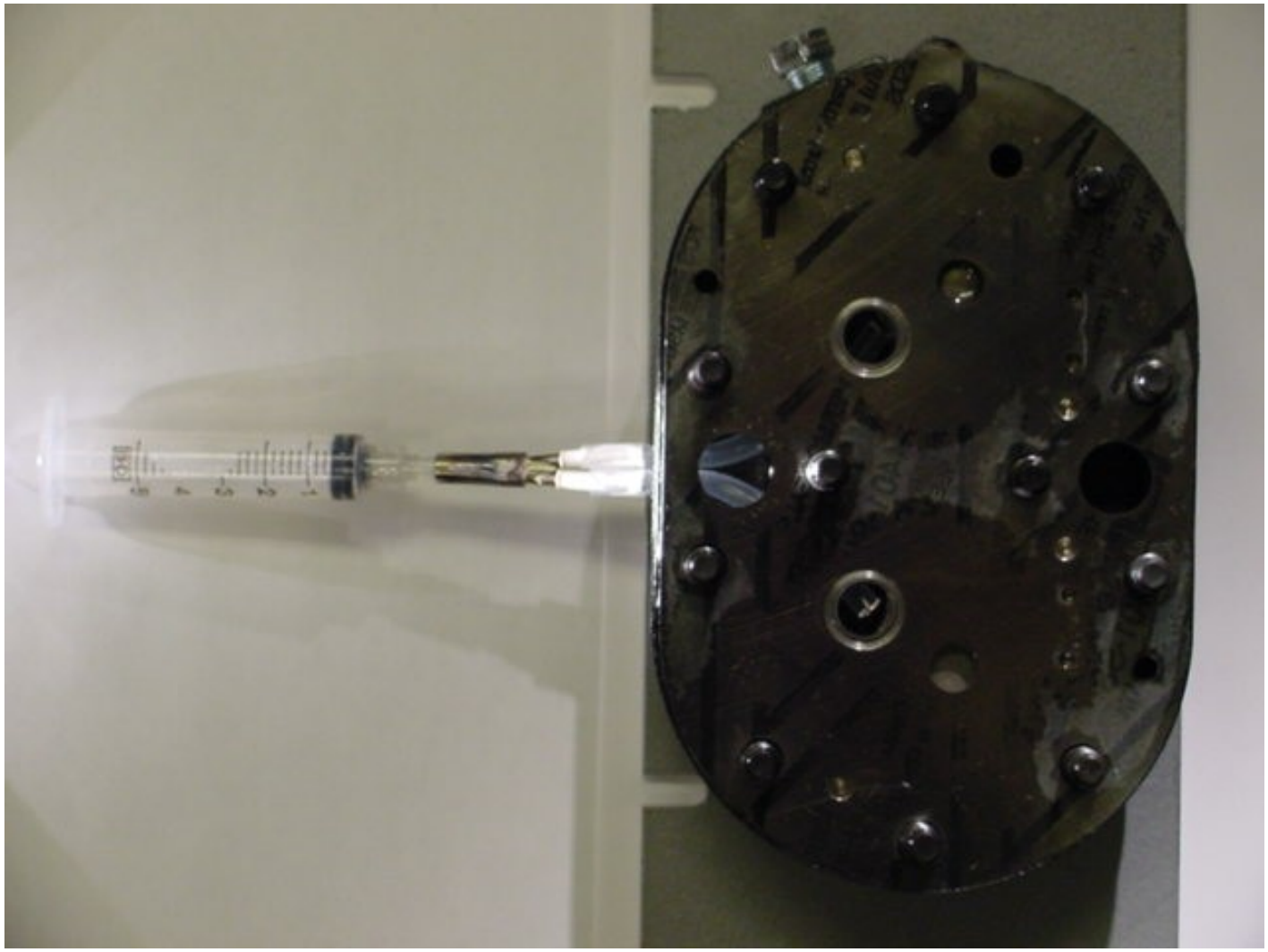
Blocked Fan Starts



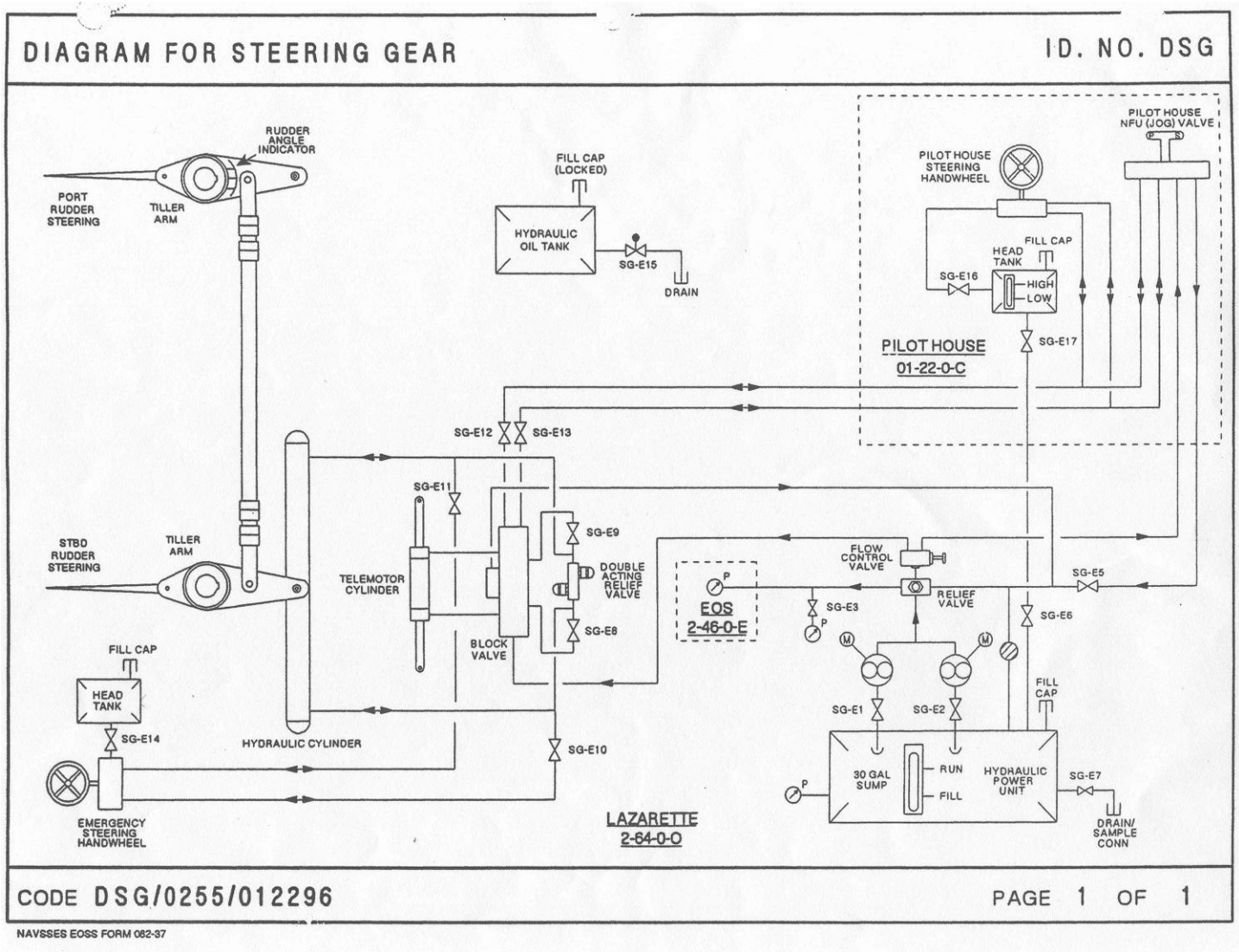
Blocked Fan Steady State



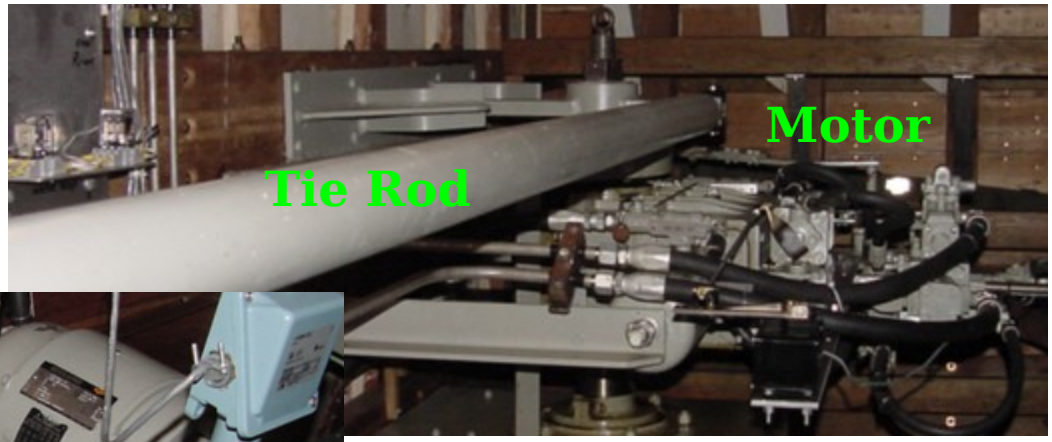
Liquid Ingestion Tests in the Laboratory

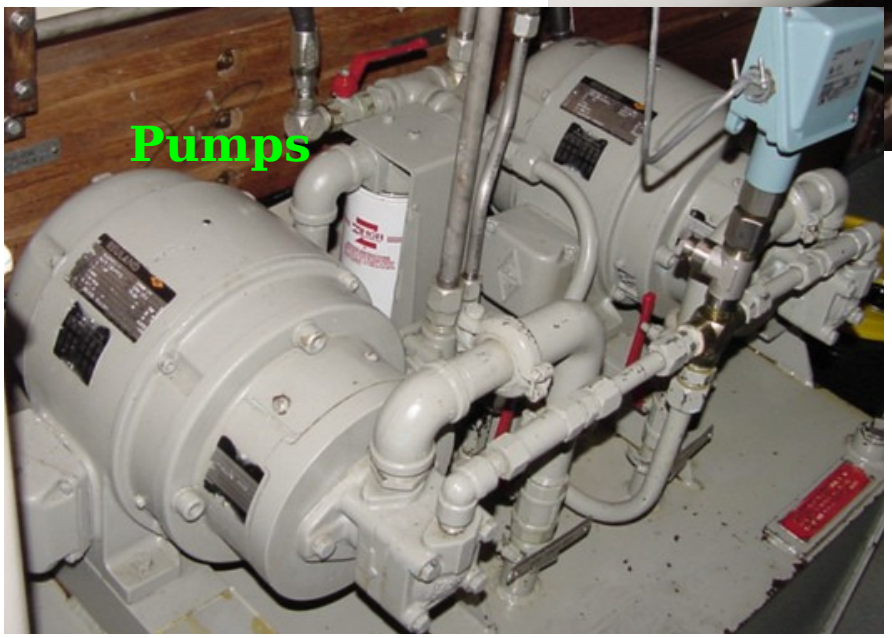


ONR YP Steering System



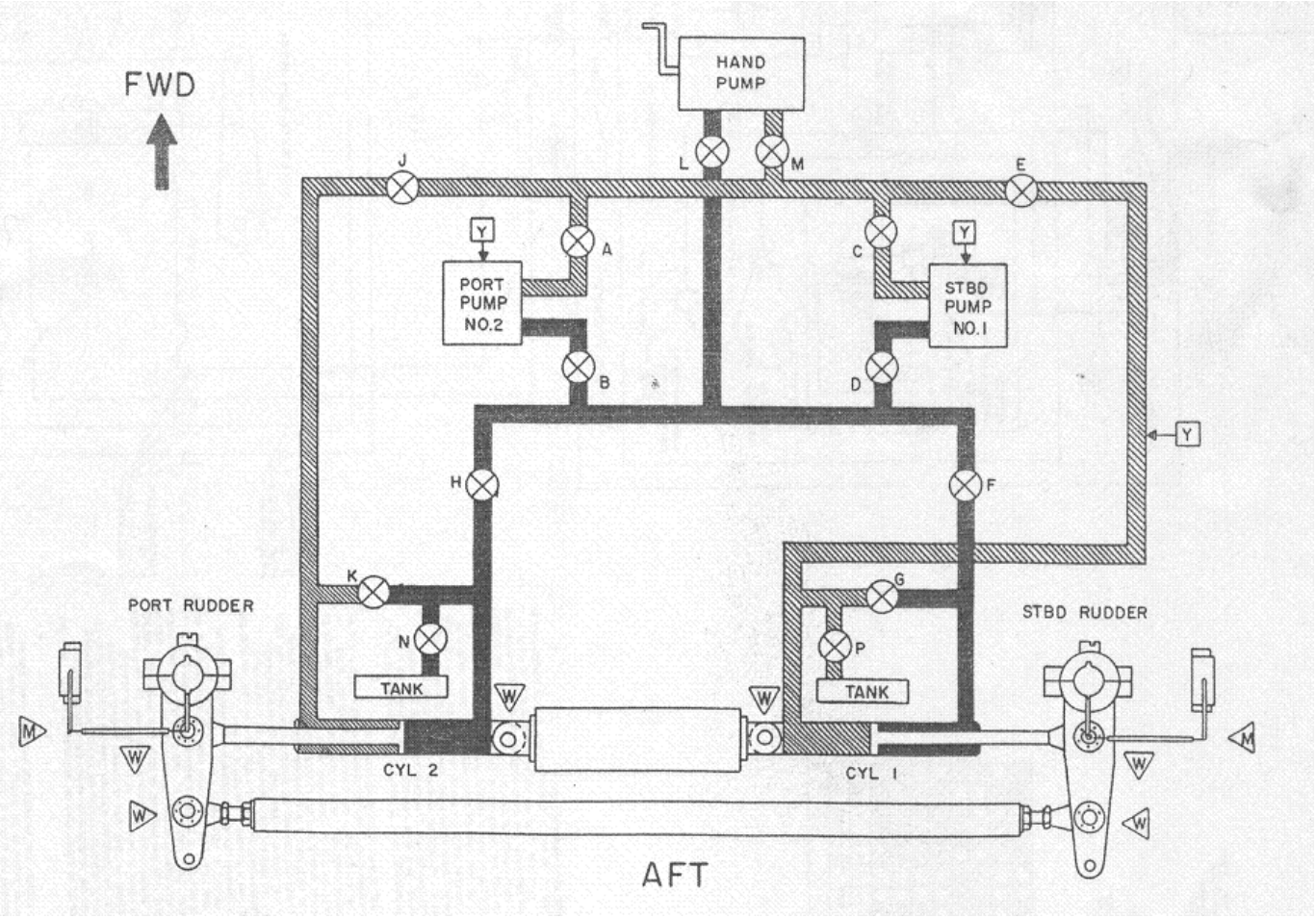
ONR YP Steering





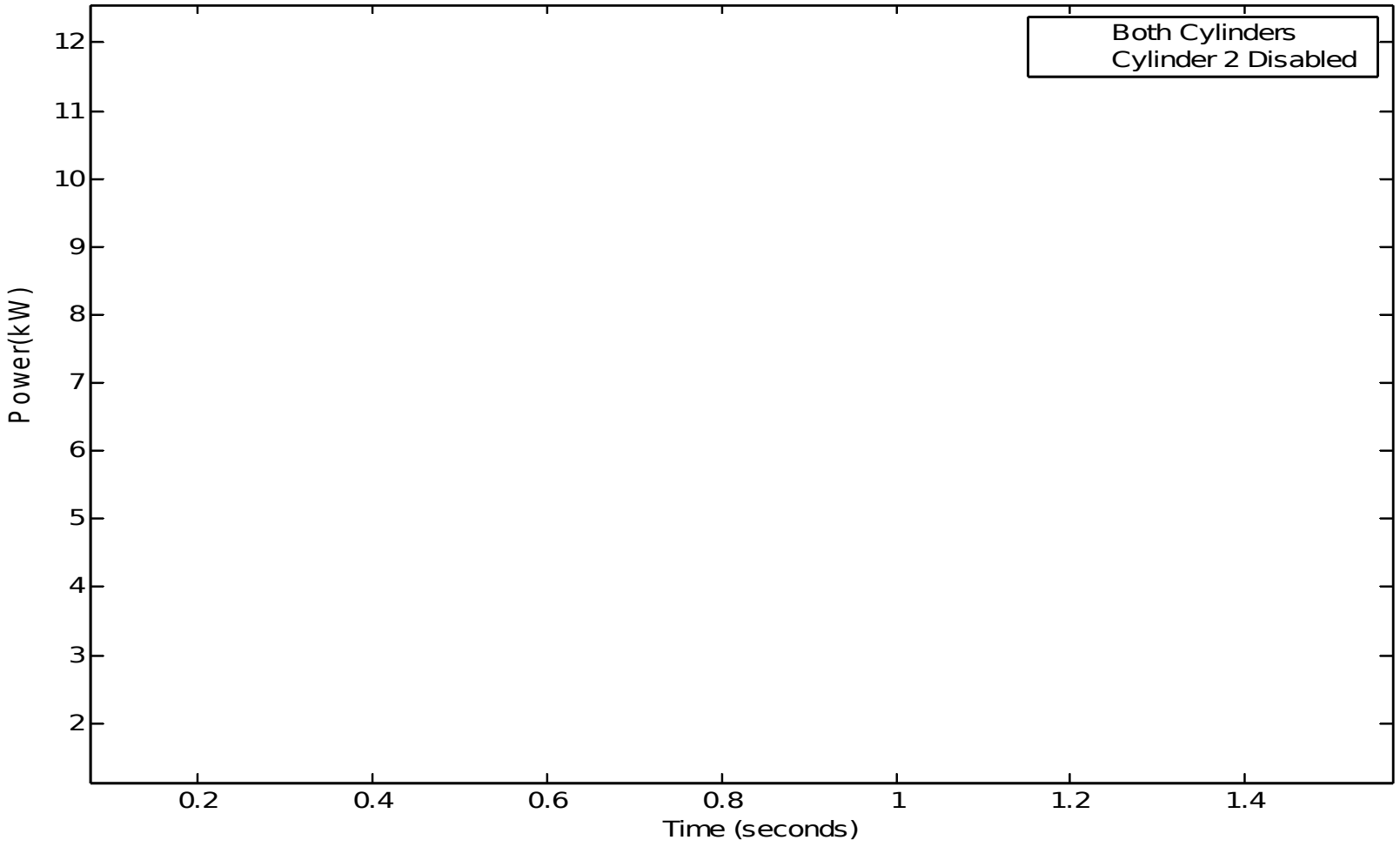
- **Two pumps pressurize common hydraulic header.**
- **NILM monitors both pumps.**

Seneca Steering System

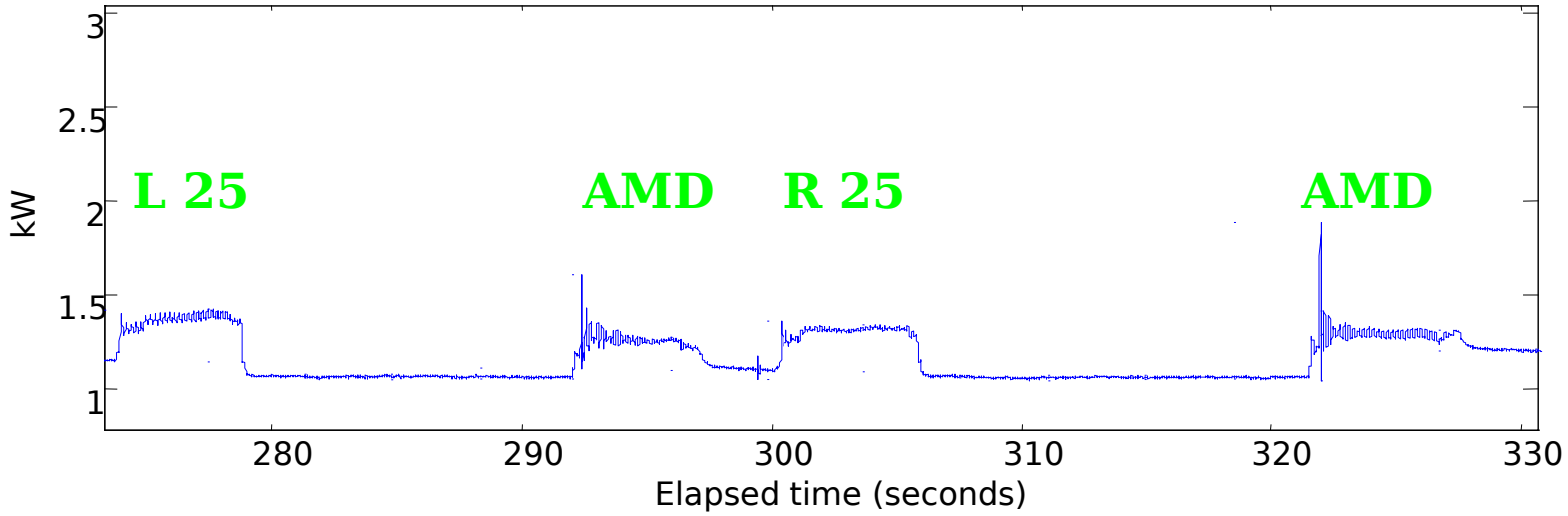


SENECA Steering Ram and Tie Rod

Steering System (ONR YP and SENECA)



Rudder Fishtailing



Comments

- NILM seems suitable for a wide variety of shipboard monitoring applications.
- Several specific diagnostic indicators are under development.
- Field tests of the performance-based monitor in the next 18 months.
- Possibly beneficial interaction with ICAS and MFM.